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SURFACE ATTACHMENT METHODS FOR RESIDENTIAL SERVICE MASTS

Report No 87-13-K

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ABSTRACT

Residential service masts are sometimes fastened to the outside walls of a building with straps and anchor-screws when access to interior structural members is difficult enough to discourage the use of through-bolts and u-bolts. Under these circumstances, care must be taken during installation to ensure that the mast fastenings are strong enough to resist strains that can be imposed by the overhead service conductors.

This report suggests fastening methods suitable for different types of wall construction and warns of situations that may render certain fastening methods unsuitable.

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To Dr. D. Mills
Director of Research

SURFACE ATTACHMENT METHODS FOR RESIDENTIAL SERVICE MASTS

D.J. Young

INTRODUCTION

This report describes acceptably-strong alternatives for attaching residential service masts to buildings in special cases when the approved through-bolt hardware is difficult to use. This most often happens in retrofit situations when finished interior walls prevent the installer from bolting through structural members of the building in the normal way. In these cases, the installer needs some practical way of attaching the mast from the outside of the house with only the outside wall as support. In this report, the term "surface attachment method" is used to refer these special ways of fastening a mast to a wall.

There are two key parts of a successful surface attachment method. First, the installer must select and properly install a suitable fastener for the type of wall surface being used. Second, and of no less importance, the installer must select appropriate load-spreading and mounting hardware to match the particular wall situation that he encounters.

This report is divided into four parts. **Background** contains important considerations that led up to this report and that should be kept in mind by inspection authorities who may have to judge the acceptability of any individual installation. **Acceptable Fasteners** is divided into sections for each major wall-construction type, and gives the proper fasteners and methods of installing them for each type of wall. **Unacceptable Fastening Methods** gives a quick summary of fasteners that are not good enough for use in holding service masts. Finally, **Acceptable Mounting Hardware** gives suggestions for hardware to spread the mast loads to appropriate parts of the wall being used.

BACKGROUND

In response to a 1985 accident and injury involving the failure of a residential service mast attachment in Windsor, Ontario, Research Division was asked to investigate methods of attaching masts for overhead services. Standard specifications for service mast hardware and its installation are part of the Canadian Electrical Code, Parts I and II, and part of the Ontario Supplement Electrical Safety Code, including the little-known Section 75 of this latter document. Many of the salient requirements of these codes as they pertain to service masts are also contained in the

Ontario Hydro Vacation Homes Electrical Inspection Guide, which is a widely-available booklet written in everyday language.

However, the rules and explanatory illustrations in these documents pertain principally to new-construction situations, and their application to retrofit service-attachments and upgrades would often be difficult and costly. This difficulty is exacerbated by the variety of wall construction types that an electrician may encounter in the retrofit trade. For these reasons, it appears that a variety of methods are in common use to avoid the necessity of installing the through-bolts and u-bolts that are called for in the code. These surface attachment methods have an obvious practical advantage over through-the-wall approaches when buildings have finished interior walls or inaccessible attic spaces. But care must be taken that the strength of any surface attachment method remains adequate in spite of the following site-specific conditions:

- uncertainty about the structural soundness of the anchoring surface
- uncertainty about the location of hidden structural wall-members
- proper selection of the fasteners (type and size)
- verification of workmanship-sensitive fastener strength
- height of the mast above the last supporting point
- stresses imposed by the length and direction of the service drop.

Overriding all of the above considerations is the fact that no CSA-approved hardware exists for the specific purpose of surface-attaching an electrical service mast to a building.

The body of this report deals only with the selection of suitable fasteners (type and length) for a variety of presumably-sound wall constructions, and with the proper installation procedures for these fasteners. Broader questions raised by each of the other site-specific considerations listed above are **not** addressed here. That some consideration may need to be given to rules and regulations that take these other factors into account is illustrated by the circumstances of the aforementioned mast failure leading to this report. A brief outline of the Windsor accident will serve as a "case study" showing that the surface attachment method is only one link in the chain to ensure a safe and satisfactory installation.

A sketch "before" and "after" the Windsor mast failure is shown in Figure 1. The three upper clamps securing the mast to the side of the house were pulled out. They had been fastened using lag screws. As will be shown later in this report, lag screws properly installed into solid wood have a satisfactory strength, but the question is immediately raised: were the lag screws in solid wood? Put another way, the first question to ask is: Given the fact that saddle-type clamps with a 4-inch spacing between the two holes were used to secure the mast to the wall, is it reasonable to expect that **both** of the two lag screws in each clamp could have been in solid wood when the wall was apparently of standard wood-frame construction with 2x4 studs on 16-inch centres?

Next, Figure 1 shows that the distance from the upper support clamp to the point of attachment of the service conductors is somewhat more than four feet. The applicable codes require that a mast be guyed when this distance exceeds four feet for a 200-A service, or five feet for a 100-A service. Therefore, a second question that comes to mind is: Should the guying requirements be strengthened when only surface attachment methods are used to secure the mast?

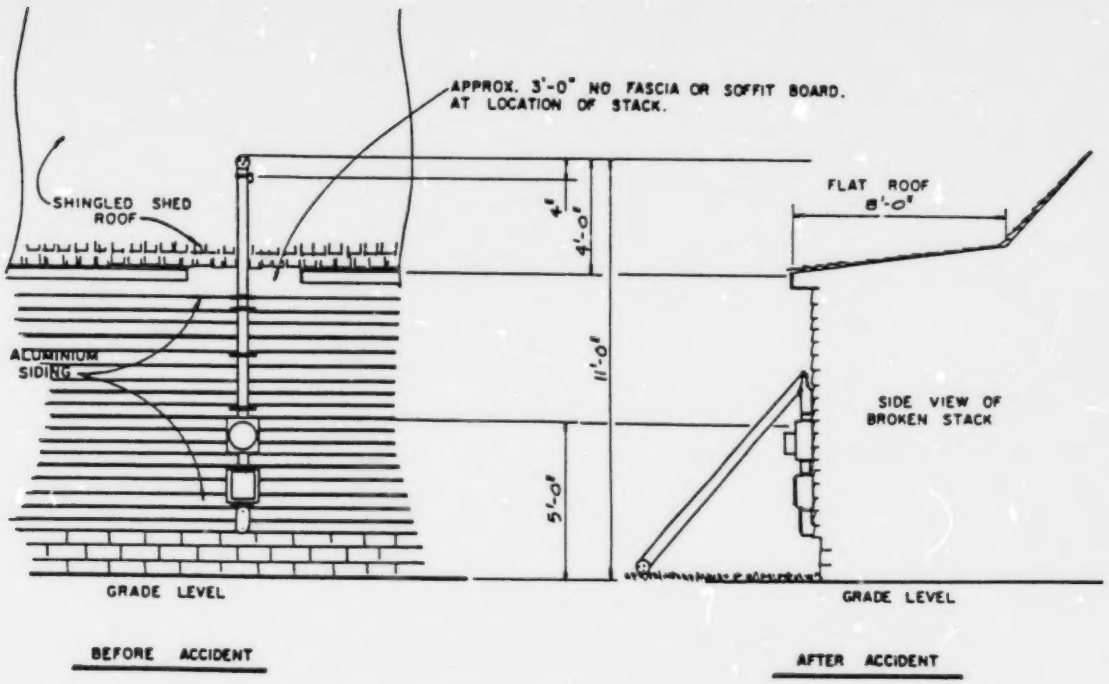


Figure 1. Windsor Mast Failure Sketch

Parenthetically, one can note that the height-above-grade of the Windsor attachment was under 11 feet. The Ontario Supplement (as amended by Electrical Inspection Bulletin 6-2-0) requires 4.5 m (~15 feet) clearance on all new services. The only way of achieving this clearance in the Windsor case would have been to guy the mast. It should be recognized that there is a reluctance in the trade to use guy wires on masts because of their "messy" appearance, the inaccessibility of many attics, and the difficulty of penetrating a roof in a leak-proof manner.

Finally, the service conductor span in the case of the Windsor mast failure was stated to be 150 feet. Section 75 of the code stipulates that 40.0 m (131 feet) is the maximum allowable span for secondary service drops. It is possible that this upper limit should be reduced in the special case of surface attachment methods, owing to the greater uncertainty of structural integrity.

In any case, the combination of long span and low attachment-point clearance may increase the incentive for the installer to overtension the span (even a foot or so of sag in the Windsor case could have apparently brought the line to within nine or ten feet of the ground). This situation could then combine with a long unsupported mast distance and a poor surface attachment strength to produce forces sufficient to break the mast away from the house. It is possible that if any one of these four conditions had not been present simultaneously, the Windsor pull-out would not have happened. This is probably the reason that certain expedient surface attachment methods have grown common in the trade – although they may not be as strong as the approved through-bolt methods, they are adequate most of the time. If they were not, the practices would have been "weeded out" long ago.

Even though some surface attachment methods have much less strength than the approved through-bolt methods, it is possible to specify surface attachments that are as strong as the mast itself **provided that the wall is sound**. The rest of this report is devoted to descriptions of surface

SPECIFICATION 26
(75-066,-042)

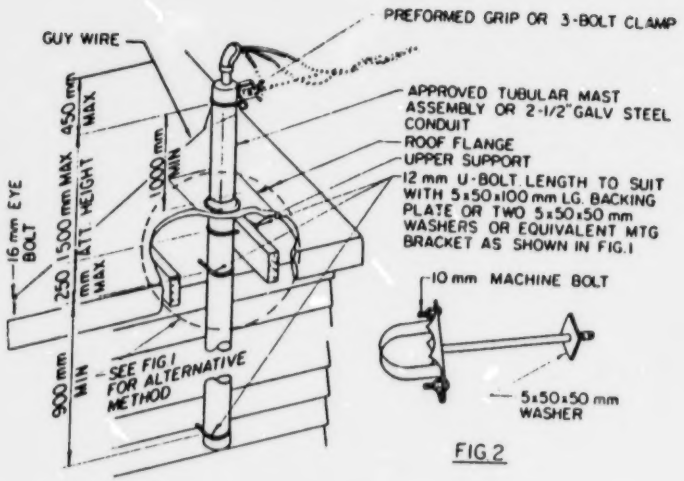

GUY WIRE
PREFORMED GRIP OR 3-BOLT CLAMP
APPROVED TUBULAR MAST ASSEMBLY OR 2-1/2" GALV STEEL CONDUIT
ROOF FLANGE
UPPER SUPPORT
12 mm U-BOLT LENGTH TO SUIT WITH 5x50x100 mm LG. BACKING PLATE OR TWO 5x50x50 mm WASHERS OR EQUIVALENT MTG BRACKET AS SHOWN IN FIG.1
16 mm EYE BOLT
250
1500 mm MAX. ATT. HEIGHT MAX.
450 mm MAX.
1000 mm MIN.
900 mm MIN.
SEE FIG.1 FOR ALTERNATIVE METHOD

FIG.2

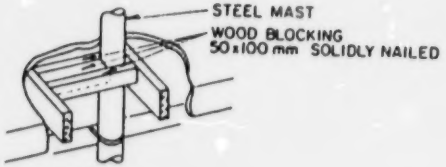


FIG.1

NOTES

1. ALL HARDWARE TO BE HOT DIPPED GALVANIZED STEEL.
2. WHERE THE MAXIMUM ATTACHMENT HEIGHT EXCEEDS 1500 mm, THEN GUYING MUST BE EMPLOYED CONNECT TO EYE BOLT FASTENED TO BUILDING STRUCTURAL MEMBER.
3. COMPRESSION CONNECTORS SHALL BE USED WHERE REQUIRED.

Service Mast

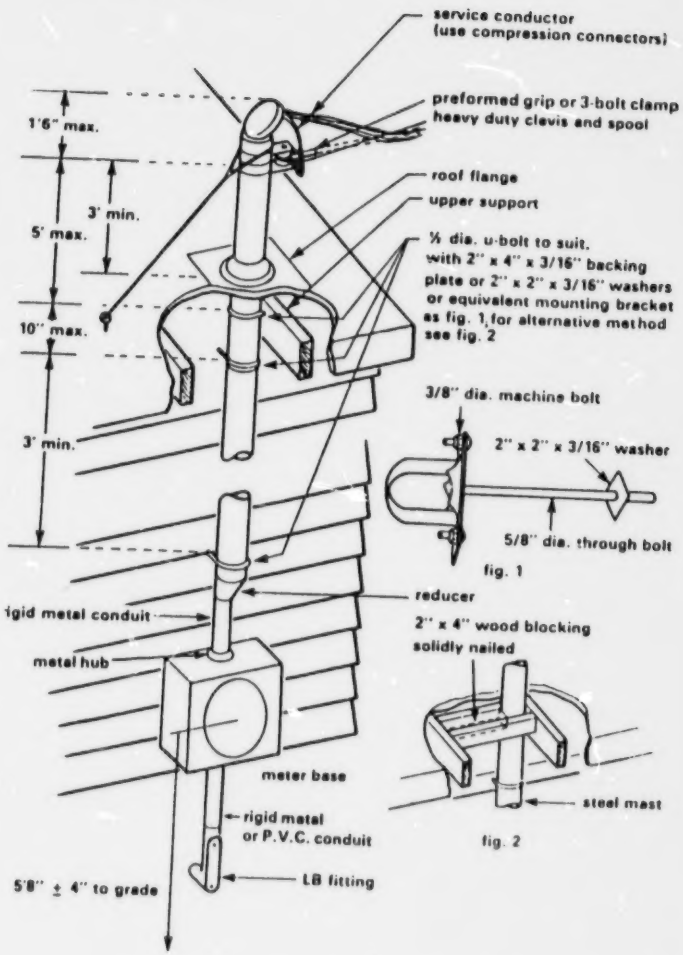

service conductor (use compression connectors)
preformed grip or 3-bolt clamp heavy duty clevis and spool
roof flange
upper support
½ dia. u-bolt to suit, with 2" x 4" x 3/16" backing plate or 2" x 2" x 3/16" washers or equivalent mounting bracket as fig. 1, for alternative method see fig. 2
1'6" max.
3' min.
5' max.
10" max.
3' min.
rigid metal conduit
metal hub
reducer
meter base
rigid metal or P.V.C. conduit
LB fitting
5'8" ± 4" to grade

fig. 1

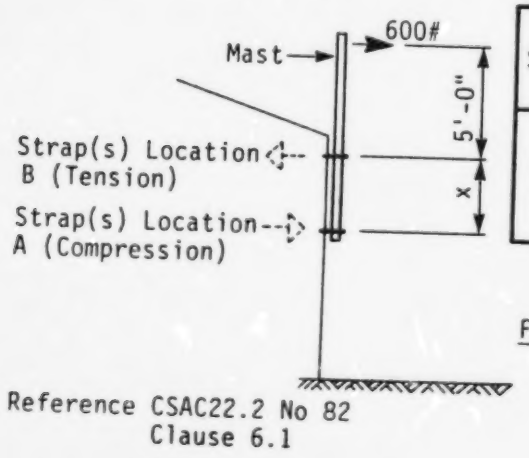
fig. 2

Figure 2. Service Mast Installation Requirements

attachment methods for various types of wall construction.

ACCEPTABLE FASTENERS

To gain some idea of the forces that mast-fastenings are required to resist, reference is made to Section 75 of the 1983 Electrical Safety Code (Ontario), and to CSA Standard C22.2 No. 82-1969, "Tubular Support Members and Associated Fittings for Domestic and Commercial Service Masts". Figure 2 reproduces "Specification 26" on service mast installation from both Section 75 and the more popular Vacation Home Electrical Inspection Guide. Figure 3 is a simple sketch that translates the 600 pound pull-force that is part of the CSA test into forces that the wall sees when the mast is installed on a building in accordance with the Electrical Code. In the worst case, a 600 pound pull at the end of a 5-foot unguyed mast projection translates into a 1600 pound pull on the upper part of the wall holding the mast.



Clamp Spacing X	Clamp A (Pounds)	Location B (Pounds)
3'-0"	1000	1600
4'-0"	750	1350
5'-0"	600	1200
6'-0"	120	750

Force At Mast Strap Locations A & B

Figure 3. Forces on Service Masts

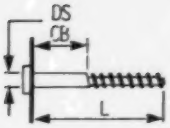
If two straps are used at the upper support point (as required by the Code), then each one will have to resist about 800 pounds. If each strap is held by two fasteners (one on each side), then each individual fastener might have to hold up to 400 pounds. This is not an unattainable strength for certain types of fastener in certain types of wall. It is also important to note that the forces on the fasteners are reduced dramatically by either reducing the extended portion of the mast, or increasing the length of mast between the upper and lower support points, or both.

Wood Frame Walls

A three-eighths inch diameter lag screw in solid wood can have sufficient strength to meet the requirements stated above. At least three inches of the lag screw must be embedded into wood to meet or exceed a strength of 400 pounds. Table 1 gives the necessary details to follow when using a lag screw to hold the mast clamp or bracket to a wall.

TABLE 1

LAG SCREWS INTO SOLID WOOD



DS = DIA Of Shank And Nominal Diameter
CB = Counter Bore Drilling Length
L = Nominal Length Of Lag Screw (Inches)

a) A Minimum Of 3" Embedment Into Solid Wood Is Required

b) Length Of Lag Screw Required:
L = 3"(min) + Thickness Of Exterior Finish & Sheathing
+ 1/4" (Thickness Of Clamp)

c) A Prebored Pilot Hole Is Required (Initial + Counterbore):
i) Initial Hole = 1/4"ϕ x (L - 1/4")
ii) CB = 3/8"ϕ x 1" + (1/4" x $\frac{L-3}{1/2}$)

d) Lag Screws Must Be Installed By Turning With A Wrench,
Not By Driving With A Hammer

e) Use Washer Under Screw Head

CAPACITY: A 3/8"ϕ Lag Screw Has An Allowable Load Of 158#/in of Length

eg: A 3/8"ϕ Lag x 3" Long Has A Capacity Of 158 $\frac{lb}{in}$ x 3" = 475#

It is important to stress that the installer must accurately locate the centre of a wall stud into which to accurately drill the pilot holes required for a proper installation. No single method exists for doing this, and in the final analysis, a combination of measurements and deductions along with test holes or nails may have to be used to locate the stud unambiguously. In some situations, the construction at corners will offer a post or a number of studs in close proximity to choose from. The installer must also choose a sufficient length of lag screw to penetrate the exterior finish and sheathing of the building and penetrate at least three inches into the stud.

Brick, Block, or Concrete Walls

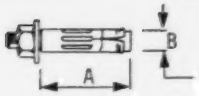
A three-eighths inch diameter expanding-type sleeve anchor is the recommended fastener for meeting the necessary strength requirements in masonry walls. Various patented sleeve anchors are available from several manufacturers, but they all share the requirement that a clearance hole be drilled into the masonry first, then the sleeve is inserted and expanded in some fashion to "key" into the material of the wall. Table 2 provides a list of suggested products and describes the proper general procedures for installing sleeve anchors.

Care must be taken that the anchor has expanded satisfactorily and is intended for the type of material in the wall. Hollow materials such as block or brick may require a different type of anchor than solid materials such as concrete. At least one manufacturer produces a fastener system employing a fast-setting epoxy that is claimed to be suitable for all masonry materials (see Appendix), but extended curing times may prevent its use at cold outdoor temperatures.

It must be emphasized that a sleeve anchor has to be installed into the middle area of a block or brick, and not into the mortar joint. This is true in spite of the fact that some types of fired brick are extremely difficult to drill for the necessary clearance hole. Also, a lag screw set into a lead plug is not an acceptable substitute for a proper sleeve anchor. Pull-out ratings for 3/8 and 5/16 inch lag screws and lead shields in solid masonary are only in the 100 to 200 pound range. If the inspection authority were to spot mast straps held on a masonry wall with lag screws and lead plugs in the mortar joints, it would be a certain give-away of an inadequate installation!

TABLE 2

SLEEVE ANCHOR INTO MASONARY WALLS



3/8 x 1-7/8 (A x B)

a) Drill 3/8" ⌀ Hole x 2" Deep In Concrete, Brick Or Block

b) Clean Hole Of Dust

c) Place Anchor Through The Hole In Strap

d) Hammer Anchor Into Drilled Hole, Hand Tighten Nut, Then Wrench Tighten 3-4 Complete Rotations

e) Do Not Locate Anchor In Mortar Joints

f) Anchor To Be Located A Minimum Of 2-1/2" From A Free Edge

Manufacturer:	Part N°:	Capacity (Safe Working Load): (Includes Safety Factor of 4)
Hilti SVA	12-214	
Isometric	HNS 38-178	
Phillips	HN - 3817	
Ramset Dyna Bolt	3717	Brick, Block 500# } Tension or Shear
Rawl Lok Bolt	5015	Conc.(3000ps.)800# }
Star	3725-17500	

UNACCEPTABLE FASTENING METHODS

Summarized from the previous section are the fasteners and installation techniques that will not give adequate strength for mast attachments.

- Lag screws that have been hammered into the wood will not have adequate strength.
- Lag screws installed without first boring the proper pilot hole may crack the wood and have inadequate strength.
- Lag screws should not be used on masonry walls. Lead shields or plugs do not have adequate strength for mast attachments.
- Sleeve anchors must not be located in mortar joints.

ACCEPTABLE MOUNTING HARDWARE

A critical step in successfully attaching a service mast to the outside of a wall is the selection of suitable hardware to spread the forces from the mast to the proper locations for the fasteners. This is most obvious in the case of a wood-frame wall where each wall stud will probably be 16 inches apart. Since two fasteners will be needed in each of three strap locations for the mast, some way must by found to span the distance between the two studs nearest the location of the mast.

The inset drawings on Figure 2 show the type of CSA-approved through-bolt that is intended for use in service mast installations. These clamps and bolts must pass a 2,000 pound pull-test as prescribed in standard C22.2 No. 82. No similar CSA-approved hardware exists for the surface attachment method, but it is well known that the strap part of the through-bolt assembly is sold

separately in the industry for this purpose. However, the distance between the holes in such straps is unsuitable for the stud-spanning task mentioned above. A better solution to the problem would be to use three clamp and channel assemblies such as the one shown in Figure 4. Such galvanized steel channel and clamp hardware is available in suitable sizes under such trade-names as Cantruss or Unistrut.

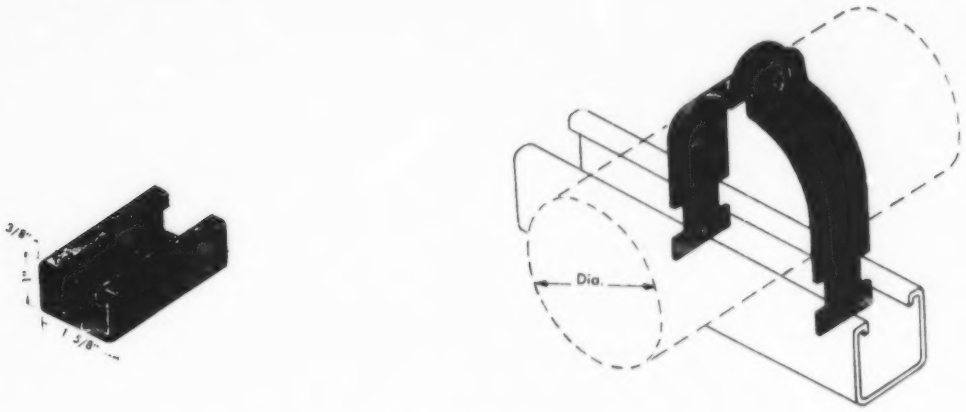


Figure 4. Cantruss® Channel and Clamp (Zinc-plated Steel)

The need to spread the mast load among two or more secure fastener locations is not confined to installations on wood-frame walls. Block or brick walls may need the flexibility afforded by such hardware in order to ensure that the position of the two sleeve anchors is not too near the edge of a brick, and not both in the same brick. In any case, it would be wise to install the required two upper mast straps in separate courses of the brick or block wall.

Figure 5 summarizes and illustrates typical surface attachment methods for various wall types.

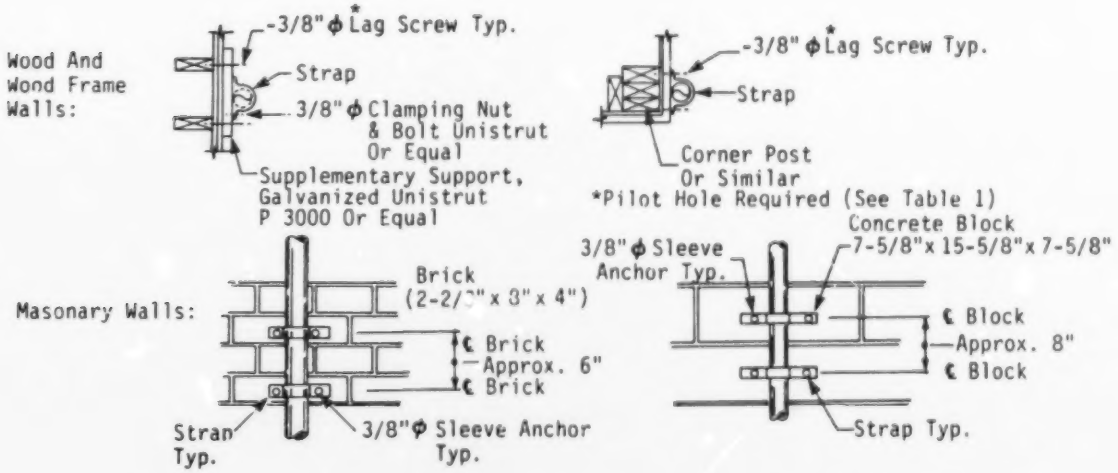


Figure 5. Typical Surface Attachment Methods

RECOMMENDATIONS

1. The acceptable fastener-and-wall combinations suggested by this report have been selected on the basis of their theoretical performance under expected situations. Further laboratory and field testing would be required to verify the performance of this hardware.

2. Standards should be developed for the appropriate load-spreading hardware needed for mast surface attachment methods in retrofit situations, and such hardware should be made available to the electrical industry.

3. Specific installation rules should be considered for services installed using surface attachment methods in retrofit situations. Such rules might reduce the spans and unsupported mast lengths permitted under such circumstances.

4. None of the attachment methods suggested in this report can be considered satisfactory if the wall itself is not structurally sound.

ACKNOWLEDGMENTS

The author wishes to thank Carl Keyes, Bruce Springett, and Armando Galasso for their assistance in the preparation of this report.

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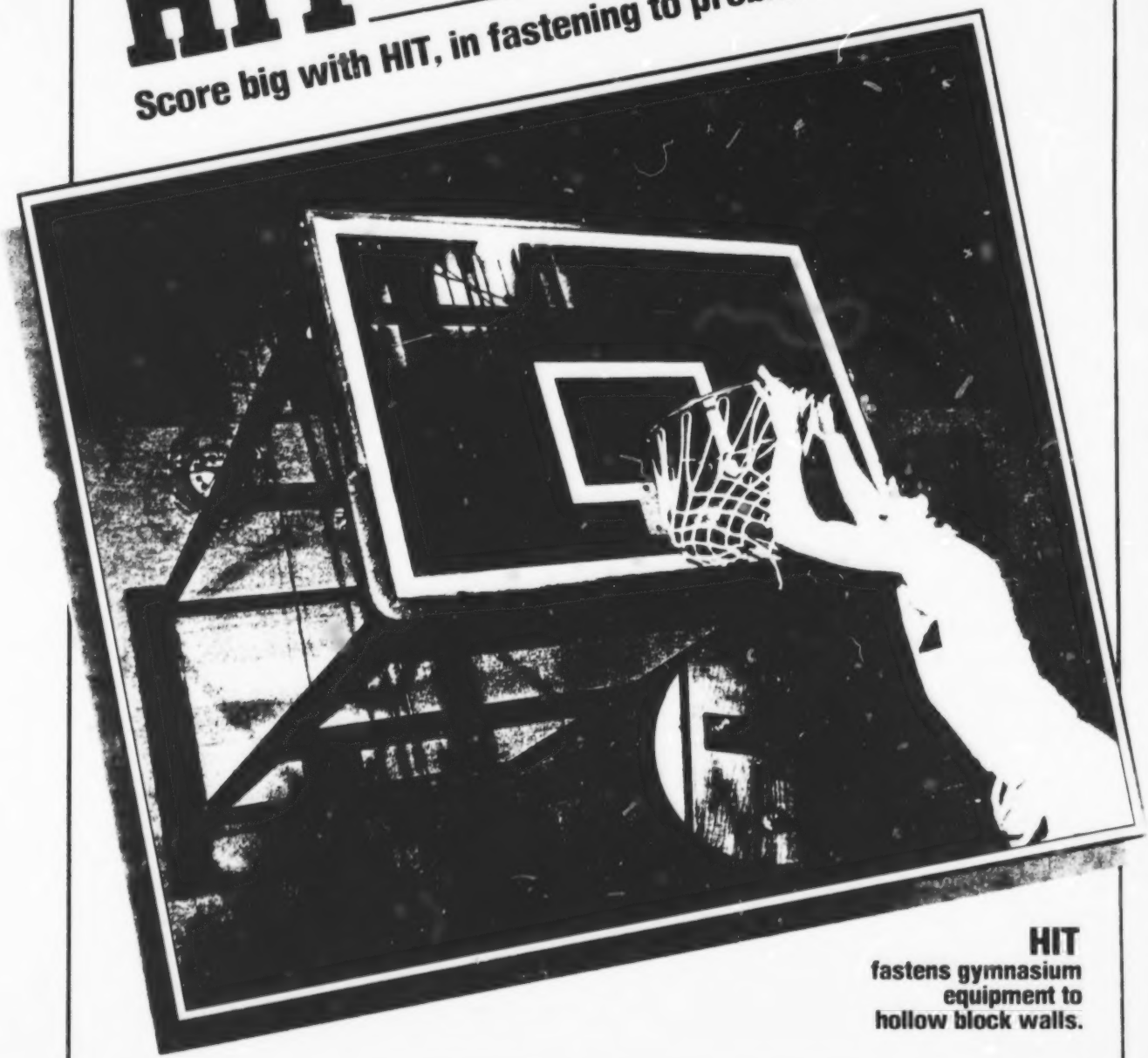
DJY:djy:ra

APPENDIX

Manufacturer's Data Sheets for an
Adhesive-Based Masonary Fastening System

HIT Hilti Injection Technique

Score big with HIT, in fastening to problem materials.



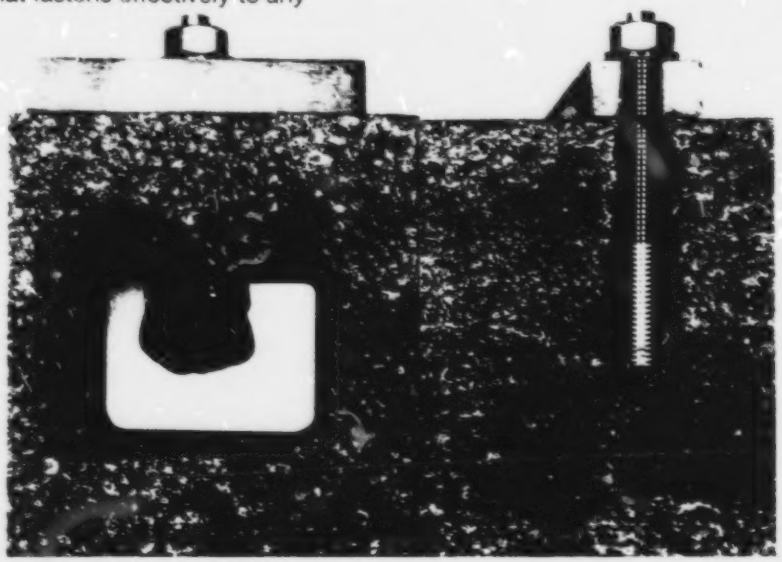
HIT
fastens gymnasium equipment to hollow block walls.

Another breakthrough in fastening technology from HILTI

HIT SOLVES YOUR FASTENING PROBLEMS

HERE'S HOW IT WORKS...

The basis of the HIT is a simple to use, strong adhesive system that fastens effectively to *any* masonry.



In hollow materials,

a sieve is inserted in the anchor hole and filled with the unique adhesive. The adhesive flows through the sieve to provide a strong "keying" action. The result: a fastening which is as strong as the base material itself.

In solid materials,

the HIT adhesive is injected directly into the hole and forms a solid bond between the anchor rod and the base material. The adhesive will even compensate for small voids or hole irregularities. The result: an anchor that's there to stay.

HERE'S HOW VERSATILE IT IS...

The versatility of the HIT systems allows you to fasten virtually any fastener or accessory to masonry. If the base material can support it, the HIT system will fasten...

- structural steel
- signs and railings
- pipe and cable tray supports
- shelving and racking
- exterior panels and curtain walls
- formwork and scaffolding
- machinery
- gymnasium equipment

... and much more.

Base Material	Ideal	Suitable	Not Suitable
1. Hollow block	•		
2. Solid block		•	
3. Hollow brick (multi-layers)	•		
4. Solid brick	•		
5. Concrete - (good condition)		•	
6. Concrete - (poor condition)	•		
7. Hollow core precast	•		
8. Rock	•		

IN ANY MATERIAL - HOLLOW OR SOLID

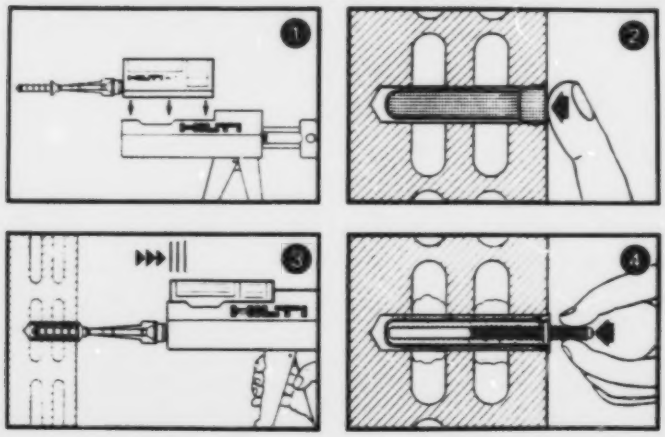
HIT - a matched system for strong masonry fastenings.

HIT Mixer -
- patented system ideally mixes the two-part adhesive.
- mixer has a built-in meter to control adhesive injection.
- no underfilling. No waste.
- adhesive is injected directly into the hole. You never touch the adhesive.

HIT Cartridge -
- a two part adhesive that bonds to masonry or concrete in as fast as 30 minutes.
- no premixing required. No mess.
- HIT cartridge will make several fastenings.

HIT Dispenser -
- a fast, effortless way to set HIT anchors. Solve your anchoring problems with the pull of a trigger.
- a simple to use tool that is ready for immediate use.
- automatically injects the correct proportions of adhesive and hardener. No dangerous mixing errors.

HIT Fasteners -
- a full complement of fasteners to meet your application needs.
- externally or internally threaded anchors are available.
- sieve system solves fastening problems in hollow materials.
- HIT rod is simply pushed into the adhesive. No complex setting tools are required.



Setting Instructions - Hollow Materials

1) Saw off cartridge end and secure mixer to C-20 cartridge. Position cartridge in dispensing tool. Pump trigger once or twice and discard adhesive ejected.
2) Drill hole in masonry and clean with a plastic bristle brush. Insert sieve into hole.
3) Fill sieve with adhesive using caulking tool. After each trigger pull, pull out dispenser to the next mark on mixer.
4) Press anchor in slowly up to the centering ring.

REACTION TIMES (Minimum cartridge temperature is +5°C)

During time vs. Air temperature

Cartridge	-5°C	0°C	+5°C	+23°C	+30°C
HIT C-20	-	-	3h	1h	45 min
HIT C-10	6h	3h	1½h	45 min	25 min

Open time (Maximum time between fastenings without changing the mixer)

Cartridge	-5°C	0°C	+5°C	+23°C	+30°C
HIT C-20	-	-	20 min	6 min	3 min
HIT C-10	45 min	25 min	12 min	4 min	3 min

HIT - Hilti Injection Technique

Supports heavy loads in masonry - Hollow or Solid

1. Dispensing Tools

Item No.	Description	Details
681296	HIT - Basic kit	Installation tool complete with case and accessories
681304	HIT P-2000 Dispenser	Installation tool

2. Cartridges

Item No.	Description	Details
681155	C-20 Cartridge	Adhesive cartridge for hollow masonry - includes 2 mixers
681171	C-10 Cartridge	Adhesive cartridge for solid materials - includes 2 mixers

3. Sieves

Item No.	Description	Hole Diameter (mm)	Sleeve Length (mm)	Box Contents
680736	HIT - S-16 Sieve	16	85	10
680744	HIT - S-22 Sieve	22	85	10

4. Anchor Rods

Item No.	(Male Threaded Rods)	Rod Diameter (mm)	Rod Length (mm)	Max. Fastening Thickness (mm)	Sieve Required	Box Contents
680868	Rod HIT M8 x 100	8	100	9	S-16	10
680884	Rod HIT M10 x 110	10	110	16	S-16	10
680900	Rod HIT M12 x 115	12	115	19	S-16	10

5. Inserts

Item No.	(Female Threaded Inserts)	Bolt Diameter (mm)	Sleeve Length (mm)	Working Thread (mm)	Sieve Required	Box Contents
889972	Insert HIT ⅜"	⅜"	80	15-35	S-22	10
889980	Insert HIT ½"	½"	80	15-35	S-22	10

Accessories

Item No.	Description	Details
	HIT Centering Rings	Contact the Hilti Sales and Service Centre for more information.
	HIT Overhead Holding Ring	Contact the Hilti Sales and Service Centre for more information.

HIT Custom Anchors

The versatility of the HIT system makes it suitable for many applications where custom sized anchors are required.

Whether it be a larger diameter rod, a longer sieve or rod, Hilti's custom anchor division can solve your fastening problem with a fast, economical solution.

Let Hilti solve your anchoring problems.

Services you can depend on.

- Expert advice on fastening problems
- Engineering staff that will design and secure approvals for HIT
- Free anchor testing or inspection
- Toll free phone ordering from anywhere in Canada Contact us - we're in the Yellow Pages under **"Fastening Equipment" and "Tools".**

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